Increasing the Reliability and Accuracy of Automated, On-Line Carbon-in-Ash Measurements

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Summary

Rupprecht & Patashnick Co., Inc., Albany, New York (R&P) has undertaken a project to modernize and upgrade our automated, on-line, carbon-in-flyash monitor, the Series 4100 Combustion Efficiency Monitor. The new monitor, named the Series 4200, incorporates recent advances in flyash analysis technologies and electronic devices to provide reliable, automated, highly accurate and precise measurement of unburned carbon in flyash samples at coal-fired power plants. Application of data supplied by on-line carbon-in-ash monitors can benefit plant operators increasing combustion efficiency thereby lowering fuel costs and ash generation rates, improve heat rate performance, optimize mill operations, and increase the availability of low carbon flyash for sale. This presentation describes the Series 4200's, its principal of operation and provides and overview of the advancements made to significantly improve the monitor's reliability and maintainability while also enhancing the quality of the percent carbon in flyash measurement. Lastly, the results of a study undertaken by R&P to evaluate the monitor's performance under actual plant operating conditions on a coal-fired utility boiler exhaust duct are summarized.

Principle of Operation

In general, the Series 4200 Combustion Efficiency Monitor measures the amount of unburned carbon in the flyash (CIA) sample using a inertial mass measurement / thermal oxidation technique. The sample analysis technique is similar to the loss-on-ignition test performed in a laboratory and directly measures the percent carbon in flyash (%CIA). However, by measuring the amount of carbon dioxide (CO2) produced by the oxidation of elemental or organic carbon present in the sample, the analysis is not influenced by variation in coal types. By integrating R&P's patented, highly accurate and precise inertial mass measurement technique (tapered element oscillating microbalance or TEOM®) with high resolution CO_2 measurements, the Series 4200 monitor can achieve a measurement resolution of $< \pm$ 0.5% CIA with a minimum detection limit of about 0.5% CIA. Furthermore, the representativeness of the %CIA measurement has been improved by integrating an (optional) dual sampling system into the system configuration to allow time-shared monitoring of two sample points in a duct.

The sampling / analysis cycle is comprised of five main steps which are automatically controlled by the monitor's onboard computer:

- Sample collection.
- Total sample mass measurement.
- Sample oxidation and CO_2 measurement.
- Data processing, calculation and reporting of % CIA.

- Filter cleaning and repositioning to start new test.

To initiate the carbon-in-ash test cycle, the filter cartridge is cleaned and moved into the sample collection position. The monitor then begins to isokinetically extract flue gas from the coal-burning boiler depositing the ash onto the filter cartridge. A pneumatically driven vacuum pump extracts flue gas from the duct through the monitor's sampling system and then through a filter cartridge affixed to the TEOM mass transducer. Isokinetic sampling conditions are maintained by the system computer based on flue gas velocity and temperature data supplied by sensors integrated into the sample probe. Flyash collection is completed in approximately 15 – 45 seconds, depending on the flyash loading in the duct being sampled. The mass transducer then weighs the deposited flyash sample. After weighing is complete (approximately 60 - 120 seconds), the sample collection filter is moved into a small, high temperature furnace by a linear slide mechanism. The furnace is quickly heated to 800ºC (in approximately 5-10 seconds) oxidizing any unburned carbon contained in the flyash sample. During the heating process, filtered, CO2-free air is supplied to the oven and channeled to a non-dispersive, infra-red (NDIR) CO_2 monitor to determine the amount of CO_2 produced during the oxidation of unburned carbon. The amount of CO_2 produced by oxidation yields the amount of unburned carbon originally present in the sample, and when combined with the total sample weight, the percent carbon-in-flyash (%CIA). To complete the test cycle, the sample collection filter is returned to the sample collection station by the linear slide mechanism. During the repositioning, the sample filter passes through the cleaning station where the filter surface is brushed and vacuumed to remove the sample residue. The entire sample collection and analysis cycle is completed in approximately 12 minutes, therefore, the monitor can provide up to 5 readings per hour.

Although there was never any doubt regarding the measurement capability of the first generation monitor produced by R&P, the Series 4100, our customers reported maintainability and operating reliability issues related to the original monitor's design. These issues have been addressed in the new monitor with an overall objective to ensure that the monitor can be maintained with one maintenance visit per week taking less than 15 minutes followed by preventive maintenance service every six months taking approximately 1 – 4 hours. The objective has been addressed by incorporating proven designs incorporated in other R&P products. Upgrades to the new monitor include using a simple, reliable, linear motion, pneumatic transport mechanism to move the sample between collection, oxidation and cleaning stations with electronic feedback from position sensors, the mass transducer and sample filter must be properly positioned before an instrument function is initiated. Power to the furnace's heating element is now thermostatically controlled through the entire heating cycle to prevent overheating the furnace, thereby extending the quartz element lifetime. Automatic, periodic purging of the heated sample line and Pitot tubes is performed to minimize the formation of blockages in the lines. A new one-piece, single-material filter cartridge has been designed to ensure that filter lifetime exceeds the once per week monitor routine maintenance interval. The electronics and sample handling cabinets are under slightly positive air pressure to prevent dust accumulation on system components and the electronics cabinet can be cooled by a simple, vortex cooler to ensure that the electronics cabinet is not overheated in the often severe environmental conditions where the monitor is located. Also, by incorporating advanced, built-in diagnostic routines and remote control/interrogation features into the system software, plant managers and system operators can verify proper monitor operation without having to visit the monitoring location.

The assessment of measurement performance and improvements in system reliability under real-world conditions is just being started. Preliminary results indicate that the monitor's design objectives will be met. On-line operating statistics and measurement results will be presented at the conference.